A Power Subsystem for a Pluto Fast Flyby Mission

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The Jet Propulsion Laboratory is currently designing a mission for the first reconnaissance of Pluto, the only known planet of our solar system not yet visited, The mission has been designed to accomplish high priority science objectives for this first reconnaissance of the planet. Pluto is now just past perihelion in its eccentric orbit and the atmosphere is condensing. This makes it essential that Pluto be explored before the 2020's when the atmosphere will be frozen to the surface for the next 200 years, A low mass spacecraft in a direct trajectory to Pluto can reach the planet in 6 to 10 years depending on spacecraft mass and launch energy.

This paper will briefly describe the Pluto Fast Flyby mission, science objectives, and the spacecraft design, The power system requirements will be detailed along with the baseline radioisotope power generator (RTG) power system design and efforts to consider alternative power sources. An advanced technology insertion effort will also be addressed.

Science Objectives

A summary of the physical science of Pluto and the exploration objectives has recently been presented by Staehle et al, (1992) from which much of the following is taken.

Pluto was discovered by Clyde Tombaugh in 1930 and has remained a largely unknown and curious body. Its eccentric, 17° inclined orbit takes the body from 30 to 50 AU from the sun, Its orbital period is 248 years. The diameter of Pluto is approximately 2400 km, about 70% of the size of earth's moon, Charon, Pluto's moon which was not discovered until 1978, is about half the diameter of Pluto's. This dual planet system is unique in our solar system, Fig. 1 shows a representation of the size of the two bodies relative to the size of the United States.

Pluto passed its closest approach to the sun in 1989 and is now relatively warm. In this condition, a tenuous atmosphere has developed, but the gasses are expected to freeze to the surface by 2020. Thus, if a reconnaissance flight is to examine the atmosphere, it must arrive at Pluto before the atmospheric collapse.

Considering the time pressures from the atmospheric conditions of planet, NASA's Outer Planet Science Working Group (OPSWG) formulated and prioritized the science objectives for Pluto exploration. The objectives were categorized as highest priority (Category 1a) or desirable but not essential for a first mission (Categories 1 b and 1c). The Pluto core measurement (Category 1a) science objectives are to characterize the neutral atmosphere, to determine the surface geology and morphology, and to conduct surface compositional mapping,

The Pluto Fast Flyby spacecraft design is intended to accomplish these Category 1 a science objectives and the first reconnaissance of Pluto with small cost, size, and mission time.

Baseline Spacecraft Design Overview

The 1992 baseline spacecraft and mission design have been described by Salvo (1993). The mission baseline is for two small spacecraft to be launched to conduct the high priority science at Pluto and Charon and relay the data to the earth. The launch is baselined for a Titan IV with a Centaur upper stage or a Russian Proton. Two solid rocket motors, a Star 48B and a Star 27, are baselined to complete the injection. The flight time on a direct trajectory to Pluto will be 8,2 years using a Titan IV/Centaur launch or as long as 13 years using a Proton launch, At

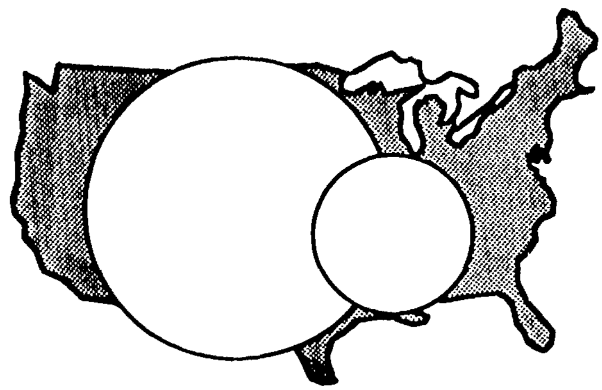

Fig. 1: Pluto (left), Charon, and the United States shown to scale.

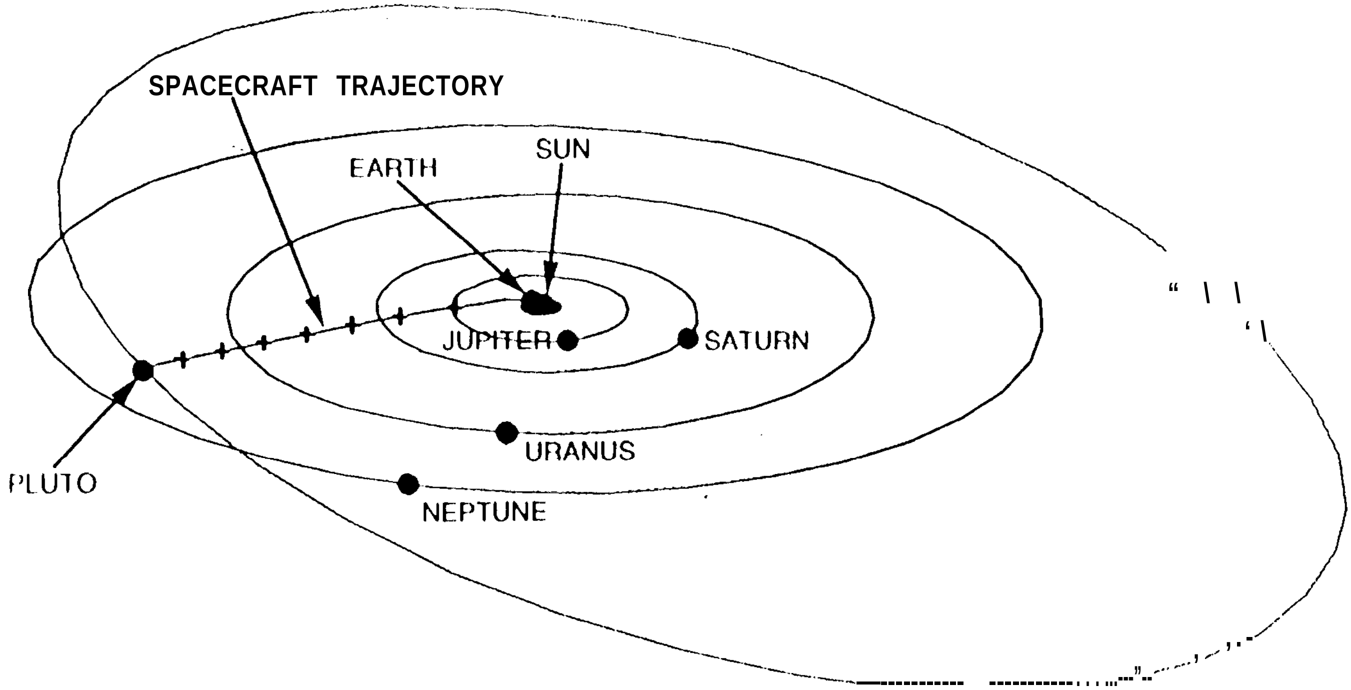

Fig. **2:** Pluto Fast Flyby 8,2 year direct trajectory to Pluto

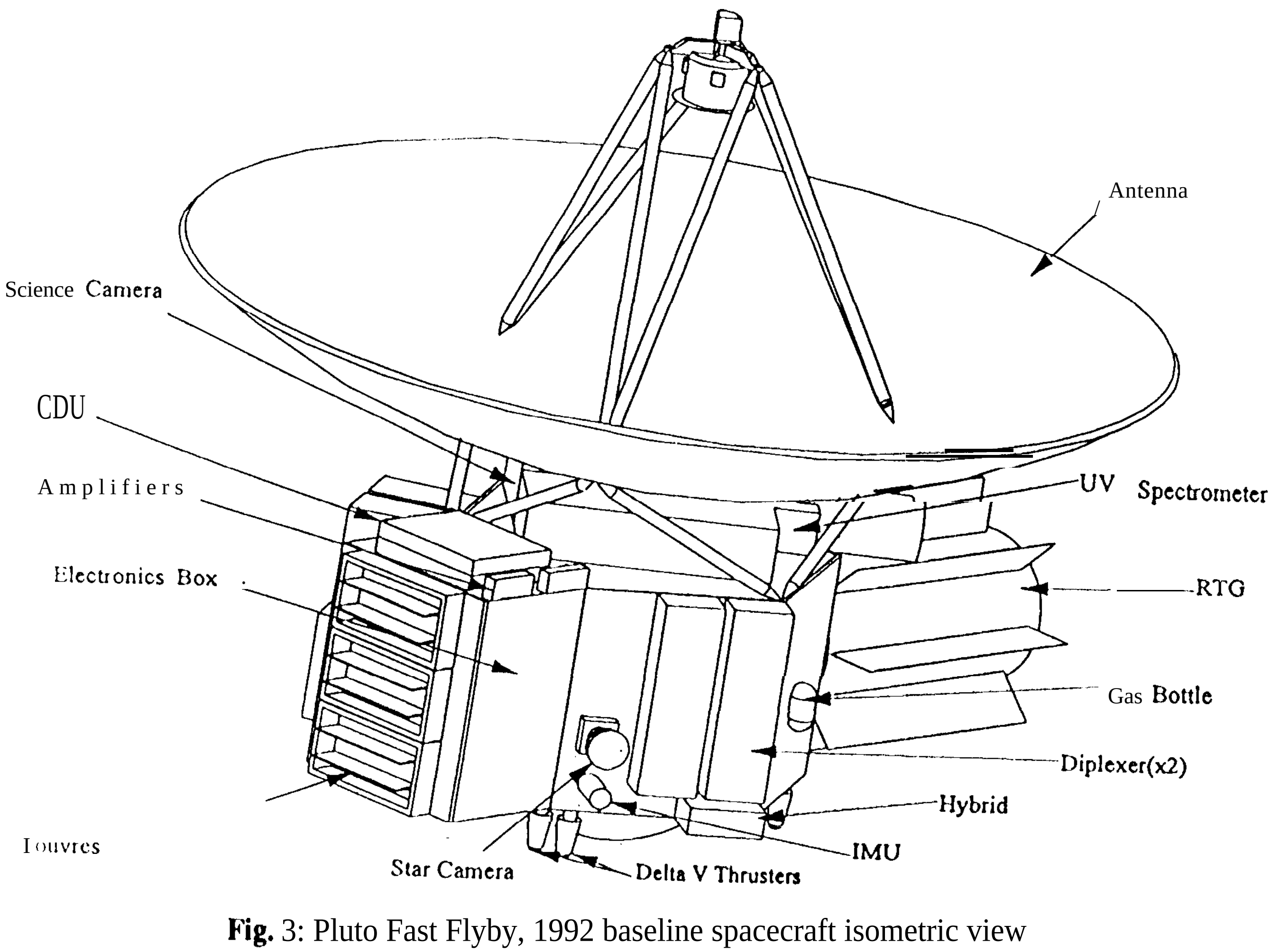

Fig. 3: Pluto Fast Flyby, 1992 baseline spacecraft isometric view encounter, the spacecraft range will be approximately 31 AU. Fig. 2 is a depiction of the direct spacecraft trajectory to Pluto in 8.2 years.

The science instruments in the straw-man payload are designed to accomplish the high priority science objectives. The instruments include a visible camera to determine surface geology and morphology, an infra-red imager for surface compositional mapping, an ultraviolet spectrometer to analyze the neutral atmosphere composition, and an uplink radio occultation experiment to map atmospheric temperature and pressure down to the surface. Up to 400 Mbits of science data will be returned at a low rate after encounter.

Each spacecraft will be fully redundant and fault tolerant, Fig. 3 shows an isometric view of the 1992 baseline design. There are no articulations or deployments. The wet spacecraft mass is estimated to be 165.3 kg, This includes 24.6 kg monopropellant and 29.5 kg contingency mass. The largest feature of the design is the 1.47 m high gain antenna; the entire spacecraft is only -1.3 m high.

The power subsystem is described below. The other subsystems include X-band telecommunications with post-encounter data return at 40 bps to the 34 m antenna of the Deep Space Network (DSN). Attitude control will be accomplished with cold gas control and a wide angle star camera/solid state gyro combination for the primary three dimensional reference. A sun sensor will provide a two axis back-up control. The sole computer on board will be a 1.S MIPS command and data computer with more than 400 Mbits of solid state memory. Propulsion will use a hydrazine monopropellant blowdown system with a cold gas pressurant. The structure will be a hexagonal aluminum bus. Thermal control will be accomplished using high efficiency blankets, radioisotope heater units (RHU's) as necessary, and by reflecting excess heat from the RTG around the spacecraft inner cavity.

Baseline Power and Pyro Subsystem

The power and pyro subsystem (PPS) for the 1992 baseline is designed to supply 65 WC at encounter and 63.8 W_e at end of mission (1 O years from launch). Additional requirements include:

- Provide regulated ±12 V, ±5 V, and 28 V to the users.
- Initiate five pyro events upon command from the CDS.
- Receive and decode commands from the c m .
- Provide telemetry through the CDS.

The baseline PPS design is diagramed in Fig. 4. The design consists of the RTG, power controller, discharge controller, DC/DC converters, power distribution, and pyrotechnic switching unit.

Due to the vast distance of Pluto from the sun, the RTG is baselined as the power source option for this mission. The small RTG described here is a re-designed version of the

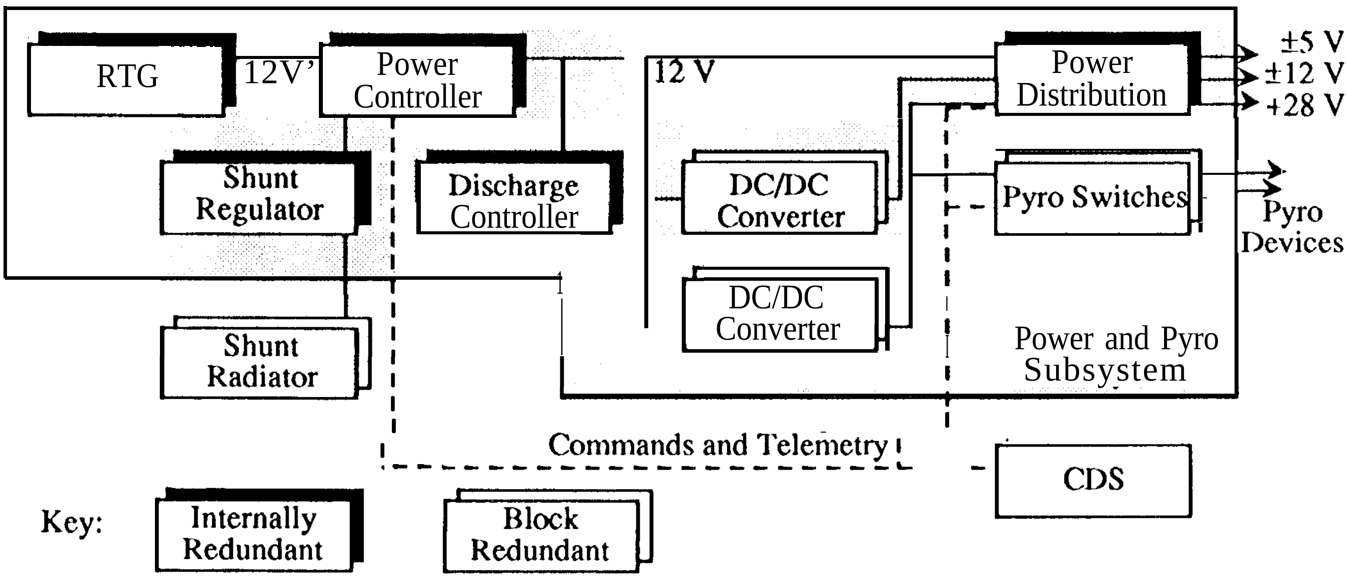

Fig. 4: Block diagram of Pluto Fast Flyby, 1992 baseline power and pyro subsystem,

RTG used on Galileo and Ulysses, and is similar to the power sources used on the Pioneer and Voyager spacecraft. These radioisotope power sources have operated as designed for up to 20 years and are expected to continue to operate for many more years. Alternatives to the RTG are also being considered. These alternatives will be detailed in an environmental impact statement along with any potential impacts that might result in the unlikely event of a severe launch accident.

An adequate discussion of the environmental impacts requires a baseline design for evaluation of potential environmental hazards and comparison with reasonable alternatives. This paper presents the initial baseline design of the spacecraft power supply and related components. The characterization of potential environmental hazards and the identification of reasonable alternatives is currently underway.

The RTG is a re-designed (scaled down) version of the Galileo RTG. This design uses 5 general purpose heat source (GPHS) modules and unicouple thermoelectric converters. The RTG is configured with redundant, dual string wiring. Due to the small size and the dual string approach, the RTG produces a 12 V output. Optimization of the RTG design is currently underway. The estimated mass is 17.8 kg,

The power controller receives power from the RTG and forms the essential and non-essential spacecraft busses. This controller provides bus voltage/current and shunt current measurement and telemetry. It also contains fault protection provisions. The estimated mass is 0.5 kg.

The power distribution unit (PDU) receives regulated power and distributes ±12 V, i-5 V and 28 V to the users, One hundred, one amp relays are assumed to provide redundant switching to up to fifty users. The maximum user load is 1 A. The PDU includes all the fuses and power command decoders. The estimated mass is 1.5 kg.

The power converters provide the spacecraft voltages. One converter provides ±12 V and ±5 V, another provides 28 V. A set of redundant converters is used for a total of four converters in the system. The maximum power for a single converter is 50 W. A minimum of 85% conversion efficiency is assumed; however, conversion efficiencies at these low powers may be lower. The estimated for the power converters mass is 0.6 kg.

The shunt regulator maintains the bus voltage for periods when the RTG power exceeds the loads. Regulation is accomplished by closed loop control of the bus voltage. A maximum of 22 W can be shunted in two regulation stages; a third stage is included for redundancy. The estimated mass is 1 kg not including the shunt radiator which is accounted with the structure.

The discharge controller provides transient power when the load current exceeds the RTG output, A maximum of 23 W for 10 ms and 33 V can be provided as required to open the cold gas thruster valves. Two capacitor banks are included for redundancy, and two DC/DC converters provide charging at 50 V. Each bank is composed of 5 capacitors in parallel. Each capacitor is rated for 100 V and 1 A. The estimated mass of the discharge controller is 1,2 kg,

Finally, the pyrotechnic switching unit (PSU) provides redundant power conditioning, energy storage, and switching for firing squibs. Command decoding and inhibits of premature firing are included. Only one event can be initiated at a time with 5 events total and two squibs per event. The PSU estimated mass is 0.8 kg.

The total estimated mass for the PPS is 23.4 kg not including the mass of the boards and connectors which are accounted with the structure. A total of six, 15 cm x 18 cm boards, spaced 3.5 cm apart, are required to accommodate the PPS components (exclusive of the RTG).

Advanced Technology Insertion

The RTG in the 1992 baseline design is the most massive single item on the spacecraft. In our 1993 effort, we are evaluating advanced technology options that could provide a lower mass power source and other options that could reduce the mass of the balance of the power system. We will define a new spacecraft baseline that may include advanced technologies. The goal of this advanced technology effort is to implement new technologies in the spacecraft design to reduce the total mass and power usage, and to reduce the flight time to Pluto.

It is premature to speculate as to the outcome of the advanced technology insertion effort at this time. Any re-definition of the power subsystem baseline with any appropriate advanced technology will be completed in the early part of fiscal year 1994.

Conclusion

A first reconnaissance of Pluto appears possible with a small spacecraft on a fast trajectory. The mission could accomplish the high priority science objectives, including the characterization of the neutral atmosphere before its collapse somewhere near the year 2020.

The 1992 baseline Pluto Fast Flyby spacecraft as described previously (Salvo 1993) could accomplish this mission, The total wet spacecraft mass is 165 kg. This paper details the preliminary design of the power and pyrotechnic subsystem, The PPS mass is 2.3.4 kg including the 17.8 kg RTG. The current effort at JPL is evaluating and developing advanced technologies for insertion into a re-defined spacecraft baseline design. Simultaneously, we are beginning the EIS process to evaluate the potential environmental impact of the RTG and to consider reasonable alternative power sources.

Now is the time to reach out to the outer most planet of our solar system. With a small spacecraft and a direct trajectory, we can complete the first reconnaissance of the planets. We can accomplish high priority science, and we can do it with a small cost relative to other outer planetary mission.

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